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THE OUTPUT OF A TRUE CORRELATOR WITH NOISY INPUTS.(U)
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6 THE OUTPUT OF A TRUE CORRELATOR WITH NOISY INPUTS.

by

10 Edward S. Eby

USL Technical Memorandum No. 2242-244-66

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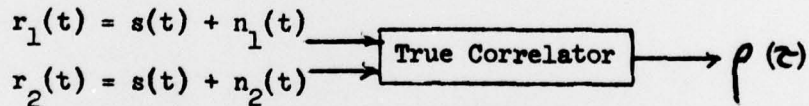
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Consider the true correlator of the figure with noisy inputs:

$$r_1(t) = s(t) + n_1(t)$$

$$r_2(t) = s(t) + n_2(t)$$

where $s(t)$ is a signal common to both inputs and $n_1(t)$, $n_2(t)$ are noise waveforms.



Figure

12 3p.

The output of the correlator is

$$(1) \rho(\tau) = \frac{\int_{-\infty}^{\infty} r_1(t) r_2(t+\tau) dt}{\left[\int_{-\infty}^{\infty} r_1^2(t) dt \cdot \int_{-\infty}^{\infty} r_2^2(t) dt \right]^{1/2}}$$

Assume the signal is not correlated with either noise and let

$$S = \int_{-\infty}^{\infty} s^2(t) dt = \text{signal power}$$

$$N_i = \int_{-\infty}^{\infty} n_i^2(t) dt = i^{\text{th}} \text{ noise power, } i = 1, 2$$

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Then

$$(2) \quad \rho(t) = \frac{\int_{-\infty}^{\infty} (s(T) + n_1(T)) (s(t+T) + n_2(t+T)) dT}{\left[\int_{-\infty}^{\infty} (s(t) + n_1(t))^2 dt \cdot \int_{-\infty}^{\infty} (s(t) + n_1(t))^2 dt \right]^{\frac{1}{2}}}$$

Evaluation of the integrals gives

$$(3) \quad \rho(t) = \frac{S \rho_{ss}(t) + (N_1 N_2)^{\frac{1}{2}} \rho_{n_1 n_2}(t)}{[(S+N_1)(S+N_2)]^{\frac{1}{2}}}$$

which we can write as

$$(4) \quad \rho(t) = \frac{(S/N_1)^{\frac{1}{2}} (S/N_2)^{\frac{1}{2}} \rho_{ss}(t) + \rho_{n_1 n_2}(t)}{[(1 + S/N_1)(1 + S/N_2)]^{\frac{1}{2}}}$$

or

$$(5) \quad \rho(t) = \frac{\rho_{ss}(t) + (N_1/S)^{\frac{1}{2}} (N_2/S)^{\frac{1}{2}} \rho_{n_1 n_2}(t)}{[(1 + N_1/S)(1 + N_2/S)]^{\frac{1}{2}}}$$

If both signal-to-noise ratios are large ($S/N_1 \gg 1$ or $N_1/S \ll 1$, $i = 1, 2$) we can use the approximation, ignoring terms higher than the first power,

$$(6) \quad \rho(t) \approx [1 - \frac{1}{2}(N_1/S + N_2/S)] \rho_{ss}(t) + (N_1/S)^{\frac{1}{2}} (N_2/S)^{\frac{1}{2}} \rho_{n_1 n_2}(t),$$

if both signal-to-noise ratios are small ($S/N_1 \ll 1$, $i = 1, 2$), then the approximation becomes

$$(7) \quad \rho(t) = (S/N_1)^{\frac{1}{2}} (S/N_2)^{\frac{1}{2}} \rho_{ss}(t) + [1 - \frac{1}{2}(S/N_1 + S/N_2)] \rho_{n_1 n_2}(t).$$

If one signal-to-noise ratio is high and the other is low (say $S/N_1 \gg 1, S/N_2 \ll 1$) then

$$(8) \quad \rho(t) = \frac{(S/N_2)^{\frac{1}{2}} \rho_{ss}(t) + (N_1/S)^{\frac{1}{2}} \rho_{n_1 n_2}(t)}{[(1 + N_1/S)(1 + S/N_2)]^{\frac{1}{2}}}$$

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give the approximation, ignoring powers higher than the first,

$$(9) \quad \rho(t) \approx (S/N_2)^{\frac{1}{2}} \rho_{ss}(t) + (N_1/S)^{\frac{1}{2}} \rho_{n_1 n_2}(t).$$

Hence, for high signal-to-noise ratios, the correlator output $\rho(\tau)$ approximates the signal autocorrelation $\rho_{ss}(\tau)$, for low signal-to-noise ratios $\rho(\tau)$ follows the noise correlation $\rho_{n_1 n_2}(\tau)$, and in the mixed case, the correlator output is mixed. In fact, if both signal-to-noise ratios are unity (0db), the true correlator output is just the arithmetic mean of the signal and noise correlations

$$(10) \quad \rho(t) = \frac{\rho_{ss}(t) + \rho_{n_1 n_2}(t)}{2}.$$

From the above calculation, we see that the correlator output will decrease in amplitude in the presence of noise, even if the noise cross-correlation is zero. If the noise correlation does not vanish, then this will appear as a bias on the true correlator output.